SCIENCE

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MAGNETIC SUSCEPTIBILITIES [1]

A. Classification of Bodies, Magnetically.—
1. Let us assume that we have at our disposal
a *uniform* magnetic field whose intensity, H,
and direction we can vary at will. H will
be expressed in Gauss and may be graphically
represented by drawing through a unit area
a number of parallel lines numerically equal
to H. Into such a field of force we may intro-
duce any substance we wish and study the
effects which that substance may produce on
the number of lines of force which thread
through the space we call the magnetic field.
Experimentally we find that any substance
when brought into a uniform magnetic field
causes a perturbation of the lines of force,
the character of which separates all substances
into two classes, viz., dia- and paramagnetic
bodies. The lines of induction are a con-
tinuation of those of the field, but in the case
of a paramagnetic substance are more closely
packed together, while in a diamagnetic body
they are further apart. Ferromagnetic sub-
stances are special cases of paramagnetism
of which the lines of induction are, relatively,
very closely packed together. A comparison
with the electric currents would make this
idea more precise.

Suppose a sphere of metal introduced into a
mass of mercury traversed by a uniform current:
the lines of flow which were originally parallel
would tend to pass in greater number through the
sphere if it were a better conductor than the
mercury, and, on the contrary, in smaller number
if it were a worse conductor. The words con-
ductivity for lines of flow and permeability for
lines of magnetic induction thus correspond to
analogous ideas.

If we let B represent the number of lines
of induction threading through unit area in

[1] Read before a joint meeting of the American
Physical Society and Section B of the American
Association for the Advancement of Science, De-
cember, 1920.

the substance, placed in a magnetic field of strength, H, then we have the relation existing between these quantities given by the equation

$$B = H \pm 4\pi I. \tag{1}$$

The number of lines of force which thread out from a magnetic pole is $4\pi m$. In equation (1) B is less or greater than H as I is negative or positive. That is to say, there is developed at opposite ends of the specimen placed in the magnetic field, H, a polarity which in case of paramagnetic substances is additive to H and makes B greater than H while in diamagnetic substances an opposite polarity is developed whose field subtracts from H and makes the resultant lines of induction further apart than the lines in the field of force. I, therefore, may be defined as the pole strength per unit area of the pole developed in the specimen, or it is the intensity of magnetization of the material examined. More frequently I is defined as the magnetic moment per unit volume, for if we take a cylinder of any material and place it in a magnetic field, then $AIl = M$, the magnetic moment of the cylinder, where A is the crossection and l is the length of the cylinder. $I = M/Al = M/V$, or the magnetic moment per unit volume. It is assumed that the poles are at the ends of the cylinder. Next divide equation (1) by H and we get

$$\mu = 1 \pm 4\pi k, \tag{2}$$

where μ is called the permeability, and k the susceptibility. $\mu = B/H$ is a measure of the power the substance has for increasing the external field. This is a quantity in which the electrical engineer is particularly interested. Further, $k = I/H$ seems also to be a factor due to properties inherently bound up with the substance introduced into the magnetic field. This factor k is called the magnetic susceptibility per unit volume. In order to get the susceptibility per unit mass we must divide the volume susceptibility by the density of the substance. As k is negative or positive so is a substance dia- or paramagnetic. It is a property in which physicists must be vitally concerned in building up a magnetic theory and developing comprehensively the architectural design of the atom. Before we have finished this discussion we must ask the question, where does the property of susceptibility lie—in the electron, atom, molecule or aggregation of molecules?

2. Next let us work with a non-uniform magnetic field such as one has between the conical pole-pieces of an electromagnet and let us give definite shape to the samples of the various materials investigated, viz., ellipsoidal form. This time we will observe the behavior of the specimens as the magnetic field is applied to them. Experimentally, we discover that here again all substances divide themselves into two groups; one class turns in the magnetic field so as to set the greatest length normal to the lines of force of the magnetic field and the other class with major dimensions parallel to the field. Not only that but those substances which set themselves normal to the field are just those which we call diamagnetic in our first experiment and those which turn with greatest length parallel are the paramagnetic elements, which also include the ferromagnetic substances. Thus we have another way in which to distinguish dia- from paramagnetic substances. It is to be noted that in a uniform magnetic field all elongated bodies set themselves parallel to a magnetic field. The reason for the orientation cited above for diamagnetism is because the poles of the substance tend to move from stronger to weaker fields.[1a]

3. As a third experiment let us work with a non-uniform magnetic field in which the variation of the field along any direction is known. Introducing our samples in the form of spheres into this field we note that they all tend to move in one direction or the other in the field, either from a point of large field intensity to one of lower or vice versa. As in our previous observations there are two classes and we find that diamagnetic substances always move from higher to lower field intensities and paramagnetic are urged in the opposite direction. Ferromagnetic bodies

[1a] Poynting and Thomson, *Elec. and Mag.*, p. 258, 1914.

distinguish themselves by their energetic paramagnetic action in the magnetic field.

The foregoing may be summed up by the following:

TABLE I.

Diamagnetic substances, μ less than unity, k negative and does not vary with H.

Paramagnetic substances, μ small but greater than unity, k positive and does not vary with H.

Ferromagnetic substance, μ greater than unity and varies with H, k positive and a complicated function of H and T.

This is practically the state of knowledge in which Faraday, Plücker, Becquerel and others left this field of knowledge fifty years ago.

B. Modern Theories of Dia-, Para- and Ferromagnetism.—The electron theory forms the basis of the modern theories of magnetism which took their rise from an extensive investigation made on the magnetic properties of bodies by Professor Curie,[2] whose name is mainly associated with the discovery of radium. Yet in this field, which we are discussing, Curie's name must always stand forth as one of the pioneers.

Based largely on Curie's work Langevin[3] has built up a theory of dia- and paramagnetism which has been extended to ferromagnetism by Weiss.[4] These theories have been of value in that they have led to new experimental evidences concerning the behavior of substances magnetically, so that in our discussion these three names, naturally, will receive more attention than others, although the contributions of others are exceedingly important. Among others to be mentioned are Honda, K. Onnes, Dewar and Fleming, Oosterhuis, Pascal, Oxley, Kunz and Owen.

In a long and careful series of investigations, Curie observed the behavior of various substances when placed in a non-uniform magnetic field, in which the observations were extended over a wide range of field intensities and temperatures. Figures illustrating the

[2] Curie, *Ann. de Chim. et de Phys.*, 5, 289, 1895.

[3] Langevin, *Ann. de Chem. et de Phys.*, 4, 70, 1905; *Jour. de Phys.*, 4, 678, 1905.

[4] Weiss, *Jour. de Phys.*, 6, 661, 1907; *Comp. Rend.*, 152; 79, 187, 367, 688, 1911.

apparatus used will be found in the original articles. The range of field strengths was from about 25 to 1,500 c.g.s. units and of the temperature from about 22° C. to 1350° C. His results are generally expressed in terms of mass susceptibility where k is positive when the substance moves toward more intense field strengths and negative when oppositely drawn. Curie examined a series of substances in each of the three groups, dia-, para- and ferromagnetic materials.

1. *Diamagnetic Substances.*—Rock salt, quartz, water, KCl, K_2SO_4, KNO_3, S, Se, I, Br, Te, P, Bi, and Sb were the substances studied. Special attention was paid to water in order to determine k absolutely as a standard of reference. Bismuth showed remarkable properties as it passed through its melting point. In every case k was independent of H and with the exception of three all gave a value of k independent of temperature and of physical state.

2. *Paramagnetic Substances.*—Air, palladium, $FeSO_4$ in aqueous solution, oxygen, glass and porcelain were the subjects investigated. Glass and porcelain were studied because they were used as the material for the container in which to test gaseous and other forms of materials. The other four paramagnetic substances were found to have a susceptibility independent of field strength and satisfied the condition that k varies as $1/T$. Beside the work on $FeSO_4$ in water Curie tried also the magnetic salts of Co, Mn and $NiSO_4$. The first two fitted in with the general law but $NiSO_4$ showed too rapid a change in its susceptibility for the inverse temperature law. The second law of Curie that k varies as $1/T$ may be expressed by saying that $kT = a$ const. which has become known as Curie's constant.

3. *Ferromagnetic Substances.*—Curie investigated nickel, soft iron, magnetite and cast iron. He paid particular attention to soft iron, studying the variation of I with T when H was maintained constant and again the variation of I with H when T was kept constant. For a certain range of temperature above the critical temperature of magnetic

transformation, the substances just listed behaved as paramagnetic materials in that I was independent of H and $k \propto 1/T$. As the temperature falls there is continuity in passing from the paramagnetic state to the ferromagnetic state. No such continuity, however, seems to exist when one passes from the paramagnetic to the diamagnetic state, which suggests that the causes underlying the two states are quite different. So far this discussion has been largely historical and is given to serve as a background for a further discussion of the theories of Langevin and Weiss which have grown out of the researches of Curie.

Curie's work seemed to indicate that paramagnetic substances would give infinite susceptibility at absolute zero. This phase of the subject has been very extensively studied. Dewar and Fleming[5] found for solid $MnSO_4$ and liquid oxygen that it did hold down to $-186°$ C. On the other hand the work of K. Onnes and Perrier,[6] Oosterhuis[7] and Honda[8] and Owen[9] seemed to show that Curie's second law is not at all true for the majority of paramagnetic substances and that furthermore a great many diamagnetic elements disobeyed the first law, viz., that they did not maintain a constant susceptibility as the temperature changed. Tables X. and XI. in the excellent paper of Dushman[10] show these discrepancies in a very striking way. These results have led Kunz[11] to remark that,

It seems to me not justified to maintain Curie's rule, as there are many more exceptions than confirmations. The same is true for diamagnetism.

[5] Dewar and Fleming, *Proc. Roy. Soc.*, 60, 57, 1897; 63, 311, 1898.

[6] Onnes and Perrier, Comm. No. 139a, Phy. Lab. Leiden. (See article Oosterhuis, *Koninklyke Akad.*, Amsterdam, 16, 892, 1913–14.)

[7] Oosterhuis, *Proc. Amsterdam Acad. Sci.*, 16, 432, 1913–14. (Look up bibliography contained in this volume of the *Proceedings*.)

[8] Honda, *Ann. d. Phys.*, 32, 1910.

[9] Owen, *Ann. d. Phys.*, 37, 657, 1912.

[10] Dushman, Reprint, *Gen'l. Elec. Rev.*, May, Aug., Sept., Oct. and Dec., 1916.

[11] Kunz, Eighth Internat. Cong. App. Chem., 22, 187, 1912.

. . . There are only very few elements which do not vary within the whole temperature range.

This weakens the foundation on which Langevin and Weiss build their theories for dia-, para- and ferromagnetism. The multitudinous works of those already mentioned with a host of others make it all too apparent that the phenomena of magnetism are exceedingly complicated. We must not, to quote Stradling,[12] expect too much of any explanation in view of the apparently contradictory facts. The theoretical and experimental investigations of Langevin and Weiss have been very productive of further experimental work and theory so that they must hold a very important place in the future development of magnetic theories. I can do no better than use the method of presentation given in the excellent résumés of the work of these two men which have been made by various English and American writers.

1. *Langevin's Theory of Diamagnetism.—* To begin with it is to be recalled that Rowland first demonstrated the fact that a moving charge created a magnetic field; if the charge moved in a circular orbit a magnetic field was produced normal to the plane of the path in which the charge moved. This forms a picture of electronic orbits which we suppose to exist in the flame for the Zeeman effect. If a magnetic field is thrown on to a group of such revolving charges, differences in period of revolution will be produced, in some cases decreasing and in others increasing the period. This gives rise to the double and triple lines which we see in the field of view of the spectroscope. This behavior of electronic orbits lies at the foundation of Langevin's and Weiss's theories. Thus according to Langevin if we introduce a substance into the magnetic field which is diamagnetic according to the tests we have already described, then the electronic orbits which we suppose surround every atom will be affected in the way we have just described them as being influenced in the Zeeman effect: some will have their periods decreased and others in-

[12] Stradling, *Journ. Franklin Inst.*, 180, 173, 1915.

creased. If the atom is built so that there are a number of electronic orbits so oriented that their resultant magnetic moment is zero then there will be no tendency for the atom as a whole to rotate, but on the application of the magnetic field there will be a tendency to alter the magnetic moment of each electronic orbit and no matter in which direction the electron is revolving the effect of the magnetic field is to create a polarity opposed to that of the applied field. If the magnetic moment of one electronic orbit is positive the effect of the external field is to decrease it and if the magnetic moment of another orbit is negative the external field acts to increase it so that the total effect is the same as that which we get from Weber's[13] theory of diamagnetism which assumes that there are no revolving electrons present to begin with but when a diamagnetic substance is exposed to a magnetic field, currents are set up in the atoms or molecules which develop magnetic fields having an opposite polarity to that of the inducing field. If the orbits of these circuits are resistanceless the currents will be maintained until the magnetic field is withdrawn again. It is to be noted that in the case of diamagnetic substances a finite magnetic moment is developed in the elementary unit with which we are dealing and which ought to have a corresponding tendency to rotate in a magnetic field. This point does not seem to be emphasized in the theory of diamagnetic substances, but as we shall see later on it is stressed in paramagnetic bodies. We know that an elongated portion of a diamagnetic substance does orient itself very definitely in a magnetic field. From the standpoint of the theory of diamagnetism just reviewed, diamagnetism must be almost a universal property of matter because we find the Zeeman effect in nearly all spectral lines of nearly all substances. We believe that the hydrogen atom has only one electronic orbit. Its diamagnetism is difficult to explain by Langevin's theory.

[13] Dushman, *Gen'l Elec. Rev.*, p. 20 of reprint from May, Aug., Sept., Oct., and Dec. issues, 1916.

2. *Langevin's Theory of Paramagnetism.*—

We have seen that in all cases the creation of an exterior magnetic field modifies the electronic orbits by polarizing diamagnetically all the molecules.

If the resultant moment is not zero, upon the diamagnetic phenomena is superimposed another phenomenon due to the orientation of the elementary magnets by the external field. The substance is then paramagnetic if the mutual action between the elementary magnets is negligible, as in the case of gases and of solutions and ferromagnetic in the case where the mutual actions play the essential rôles. As soon as the paramagnetism appears it is, as a rule, enormous in comparison with the diamagnetism and therefore completely conceals it. This explains the discontinuity between paramagnetism and diamagnetism; paramagnetism may not exist; but if it does, it hides completely the diamagnetism.

Therefore, substances whose atoms have their electrons in revolution in such a way that their effects are additive, are paramagnetic. The atoms of such substances may be looked upon as elementary magnets.

If we think of the elementary magnets at ordinary temperatures as being in a state of agitation then the tendency of the elementary magnets to orient themselves in a magnetic field will be opposed by the thermal agitation of the elementary magnets and they will settle down under a state of statistical equilibrium.

3. *Weiss's Theory of Ferromagnetism.*— Langevin has given a theory of dia- and paramagnetism and largely assumes ferromagnetism as a special case of paramagnetism. That ferromagnetism is a special case of paramagnetism will, I think, be conceded by all, but to explain more completely the phenomena attendant on ferromagnetism, Weiss has extended the theory somewhat by saying that to explain the varied phenomena as we find them, there must be associated with the turning of the elementary magnets something which acts like an extra magnetic field in addition to the external field applied. After considering all phases of the problem, however, and showing that he can explain many of the existing phenomena by means of this extra or intrinsic molecular field he is forced to admit that this "molecular field must be attributed to the

action of forces whose nature is still unknown." What must be the nature of these forces between elementary magnets? Weiss argues that they are neither magnetic nor electrostatic. These are questions to be left to the reader.

An attempt to correlate the many researches which have followed in the wake of Curie, Langevin and Weiss leaves the reviewer with a feeling of utter helplessness. The experimental work, in many cases, might well serve as examples of the highest type of modern physical research, but, when it comes to the various theories advanced, one must confess to a feeling that it is a good guessing contest in which one is as good as the other.

Out of Weiss's work, however, has grown a conception that seems destined to have some real meaning as we learn more concerning magnetic phenomena, that is, the magneton. Just as we have found that the electron seems to be the unit out of which we build all other electrical charges so here Weiss finds a similar analogy in that the magnetic moment per gram molecule of various substances seems to be small multiples of a common magnetic moment, equal to 1,132.5. Since we think of magnetic fields as due to moving charges can the magneton ever be so fundamental a concept as is the electron?

C. Seat of Magnetic Powers.—As we go over these various theories one is impressed by the recurrent words, orientation, rotation, revolution, change in magnetic moment, electronic orbits, etc., and then one begins to wonder as to how much magnetic phenomena really depend on these phases of the subject.

1. When a piece of iron, nickel or cobalt is placed in a magnetic field, what grounds have we for saying that the molecules, atoms or elementary magnets of the specimen are actually turned in situ by the external magnetic field? Does our affirmation of this question rest upon the fact that Ewing[14] once on a time pivoted a number of little magnets on needle points and showed how

they behaved in a magnetic field and said this is the picture of a group of elementary magnets? Small magnets will turn on axes as Ewing showed they would and the logic is that the elementary magnets will also, but note that Ewing would have found hysteresis and B-H curves even if his little model magnets had not turned at all. Ewing's magnets did turn and the logic of the argument has tremendous confirmation in the work of Swinburne[15] who predicted as a consequence of Ewing's theory that if a piece of iron is rotated in a very strong magnetic field and the elementary magnets are held in alignment steadily as the iron cylinder is rotated there will be no changing from one configuration to another which may be unstable and thus dissipate magnetic energy into vibrational energy; consequently there will be a suppression of hysteresis. This was experimentally confirmed. Another verification is found in the experiment of Waggoner and Freeman[16] on the suppression of hysteresis by a longitudinal A.C. magnetic field, where the same kind of explanation as Swinburne's might be applied. This suppression of hysteresis seems to be closely associated with a certain degree of freedom to rotate, as for instance Rosenhain[17] points out that when an element whose atomic volume is greater than that of iron with which it is alloyed, the effect of the added element is to decrease the hysteresis. The increased atomic volume, from a mechanical viewpoint, makes larger interstices between the elementary magnets which permits of greater freedom to swing. If we have a theory to explain dia-, para- ferromagnetism then that same theory, in order to be a comprehensive magnetic theory, must explain all magnetic phenomena. At this point an outline might be introduced as an aid to keeping one's bearing when dealing with general magnetic phenomena.

14 Ewing, *Magn. Induc. in Iron*, etc., p. 348 et seq., 3d ed.

15 Swinburne, Baily, *Phil. Trans.*, 187, 715, 1896.
16 Waggoner and Freeman, *Gen'l Elec. Rev.*, p. 143, Feb., 1918.
17 Rosenhain, "Introduc. to Phys. Metallurgy," p. 110, 1915.

TABLE II

I. Induction Effects.
  1. Relation between field strength and magnetic induction, permeability, susceptibility, coercive force, retentivity, hysteresis, etc.
  2. Dia-, para- and ferromagnetism.
  3. Terrestrial magnetism.
  4. Alternating currents.
  5. Inductive effects as influenced by temperature, mechanic strains, aging, etc.
  6. Relation between susceptibility and chemical properties.
II. Mechanical Effects.
  (a) Reaction effects between magnetic fields.
    1. Attraction and repulsion of magnetic poles.
    2. Motion of electric conductors, solids, liquids and gases, carrying currents when placed in a magnetic field.
    3. Hall effect and its reciprocal relations.
  (b) Magnetostrictive Effects.
    1. Joule effect. Its reciprocal relations.
    2. Villari effect.
    3. Wiedemann effect. Its reciprocal relations.
    4. Volume change. Its reciprocal relations.
    5. Change in resistance due to a magnetic field.
    6. Production of sound.
    7. Piezo- and pyromagnetism.
    8. Magne crystallic action.
    9. Effect of magnetic field on thermo-electric phenomena.
III. Magneto-optical Effects.
  1. Faraday effect.
  2. Kerr effect.
  3. Zeeman effect.
  4. Magnetic double refraction.

Naturally one might question some points in this classification. Certainly changes would be made if we knew more about the subject. Whatever the arrangement of subjects a complete magnetic theory must explain all of the above phenomena. This is a real task. In particular, the present magnetic theories sidestep those phenomena listed above as magnetostrictive effects, which as the outline indicates is about half of the various magnetic effects. If the rotation of the elementary magnets due to an external magnetic field explains ferromagnetism then one may properly ask if the rotation of the elementary magnets might not also explain the magnetostrictive effects because these effects appear in ferromagnetic substances. Poynting and Thomson[18] have called attention to the fact that these magnetostrictive effects are yet to be explained on the molecular hypothesis. They state,

It would obviously require some further assumptions as to molecular grouping or as to molecular dimensions in different directions.

The latter assumption has been a suggestive one and some progress has been made along this line, many of the magnetostrictive effects may be explained as being due to the orientation of elementary magnets whose dimensions vary in different directions. The work of Barnett,[19] Einstein[20] and deHaas and J. Q. Stewart[21] favors the idea of an orientation of the elementary magnet. Indeed our evidence seems very strong that rotation of the elementary magnets due to an external field is a part at least of all ferromagnetic phenomena.

The brilliant and highly significant work of the two Comptons[22] and their co-laborers[23] on the problem of the ultimate magnetic particle has a very important bearing on this phase of our discussion. Their interpretation thus far seems to argue against anything turning due to an external field unless it be something inside of the atom. If it is something inside of the atom it would seem difficult to explain the Heusler alloys or that bulk iron is ferromagnetic; while ferrous sulphate is paramagnetic and potassium fer-

[18] Poynting and Thomson, "Elec. and Mag.," p. 201, 1914.

[19] Barnett, *Phys. Rev.*, 6, 240, 1915.

[20] Einstein and deHaas, *Verh. d. deutsch. Phys. Ges.*, 17, 152, 1915.

[21] Stewart, *Phys. Rev.*, 11, 100, 1918.

[22] Compton and Trousdale, *Phys. Rev.*, 5, 315, 1915.

[23] Compton and Rognley, *Phys. Rev.*, 16, 464, 1920.

rocyanide is diamagnetic. No cataclysm of the atom has occurred in these chemical changes. On the other hand if we turn to magnetostriction for help in interpreting the work of the Comptons and explain magnetostriction as due to the orientation of the elementary magnets it would appear that their negative results may be due to the fact that they worked at only one field strength, whose value is not given in their papers, and at that field strength the orientation had not proceeded far enough to give measurable effects. For instance, in the case of an iron rod, as the magnetic field strength is increased from zero upwards, the rod first elongates and then shortens, becoming shorter at high field strengths than in its virgin state. At that field strength where the length once more becomes equal to the original length, at that point one would expect negative results in the work of the Comptons. In iron this field strength is about at the point where saturation occurs. From the magnetostrictive viewpoint the Comptons should find maximum effects at those field strengths where maximum changes in length occur. The Comptons used magnetite which is quite different from iron in the manner in which its length changes in a magnetic field. Yamada found that at several hundred Gauss field strength, it was still increasing its length and no maximum attained. The question may legitimately be raised as to whether the orientation of the elementary magnets had been carried on sufficiently to give the Comptons the effects they were looking for. A further study of the Joule effect in magnetite is being started to throw more light on this subject.

2. Would negative electrons revolving in orbits or negative electrons rotating, à la Parson, alone suffice as a picture of the elementary magnet? The theories we have so far discussed seem to convey the idea that they would. Why not attribute magnetic phenomena to a positive nucleus spinning on its axis? Barnett's work indicates the negative charge as the portion of the elementary magnet which is in motion. This does not,

however, debar the positive nucleus from contributing some part of that property which we know as susceptibility and which we have been discussing. In other words induction may be a part of the property of the nucleus and we shift at least a part of that property from the mass to the elementary magnet.[24] What is it that gives magnetic characteristics? These are questions which our general subject of susceptibility raises. There are a number of items which, as it seems, bear upon these queries. Maurain[25] deposited thin films of iron and nickel and found he had to have a certain thickness of film before he obtained definite magnetic properties. For iron this was 8.3×10^{-8} cm. and for nickel, 20×10^{-8} cm. Wilson[26] in measuring the magnetic fields in a rotating iron cylinder arrives at the size of a magnetic particle as 10×10^{-8} cm. which checks fairly well. Hull,[27] working on the X-ray analysis of iron and nickel finds the distance of 2.47 and 2.50×10^{-8} cm. respectively as the distance between nearest atoms. These values seem to be commensurate. As already pointed out the spacing of the atoms seems to play a very important part in magnetic phenomena. Hull calls attention to the fact that it might be anticipated that ferromagnetic substances would have the same crystal structure. This is not true for iron and nickel are different according to Hull's observations. It is evident that ferromagnetism does not depend upon any particular arrangement of atoms but more probably upon distance between atoms which would explain the fact that this property is lost when the temperature is increased beyond a definite value. A center cubic arrangement may be more favorable to ferromagnetism, but is not a principle or essential factor. Arnold and Hicks[28] state:

The elements giving iron high permeability and

[24] *Phys. Rev.*, abstract, Feb., 1911. *Phys. Rev.*, 34, 40, 1912.

[25] Maurain, *Jour. de Phys.*, 1, 151, 1902.

[26] Wilson, *Proc. Roy. Soc.*, 69, 435, 1902.

[27] Hull, *Phys. Rev.*, 14, 540, 1919.

[28] Arnold and Hicks, *Nature*, Apr. 17, 1902.

low coercive force are those which cause it to crystallize in large crystals.

Aston[29] also says:

It seems true, other things being equal, that the heat treatment which will give to pure iron a coarseness of crystallization, and above all a uniformity and regularity of such structure will be accompanied by a low coercive force, and the effect of heat treatment is augmented by the addition of silicon or analogous elements, as arsenic or tin, all of which increase the coarseness of crystallization of the material.

It seems to be generally conceded that manganese is the essential constituent in the Heusler alloy. We don't know the magnetic properties of manganese any too well but its being associated so closely with iron, cobalt and nickel in the periodic system indicates the possibility of its possessing latent magnetism which under favorable conditions becomes active. Ross suggests that the presence of the other metals beside manganese exerts a helpful influence in making the manganese elementary magnets farther apart and so increasing its magnetic activity by the removal of the intense intermolecular forces which are supposed to act in the metal manganese. This point of view is further corroborated by the fact that the susceptibility of copper containing minute quantities of iron is far greater than that calculated from the amount of iron present. One of the most thorough researches undertaken on a phase of this subject was by Perrier and Onnes[30] who studied the susceptibility of a liquid mixture of oxygen and nitrogen and the influence of the mutual distance of the molecules of oxygen upon paramagnetism. In this work the oxygen at the low temperature is paramagnetic and inasmuch as the nitrogen did not enter into chemical combination with the oxygen it was possible to separate the oxygen molecules as much as desired by making the percentage of nitrogen larger. Their general results may be summed up by saying:

[29] Aston, *Trans. Faraday Soc.*, Vol. 9, July, 1913.

[30] Perrier and K. Onnes, *Proc. Roy. Acad. Amsterdam*, 16, 901, 1914.

The specific magnetization coefficient of oxygen becomes considerably greater, in proportion as the concentration diminishes.

There is much to be investigated along this line.

This discussion leads inevitably to the question as to where we shall locate the origin of the property of susceptibility? Will a group of electronic orbits account for magnetic phenomena or must we have added to their effect that which arises from the positive nucleus? Could we have a group of small coils to replace the group of little magnets with which Ewing once worked and obtain results such as he did? I have been working on this problem the past two years and so far have not been able to realize experimentally what Ewing did. It must be emphasized again that Ewing in his classical experiments worked with elementary magnets in which each elementary magnet itself showed all the properties which the group did. An attempt to explain the magnetostrictive effects on a molecular hypothesis makes it look very much as though one needed another factor to add to the electronic orbit to explain that particular field of magnetic phenomena.

Space forbids to give all the reasons why one is led to think of the atom as the seat of the phenomena we meet with in magnetism, or that the atom is the elementary magnet. The classical argument against this point of view is that the iron atom is ferromagnetic, ferrous sulphate is paramagnetic and potassium ferrocyanide is diamagnetic. Iron is a constituent of all three. Why this wide divergence of property? From preceding arguments it would appear that interstitial relations might answer the question. Oxley[31] put it another way by saying, in speaking of diamagnetism, that the molecular structure is distorted by the near approach of the other molecular structures so that the self induction of the electronic orbits is affected. The magnetic theories of Langevin and Weiss are essentially atomic theories and that the susceptibilities of the elements is

[31] Oxley, *Phil. Trans.*, 214 (*A*), 109, 1914.—215, *A*, 79, 1915.

related to the atomic numbers in a definite manner is brought out by the curve which Harkins[32] has worked out and in a more striking fashion the curve given by Dushman[33] relating the logarithms of the susceptibilities of the elements to the atomic numbers. The curves showing these relations indicate a very definite tie between them and yet there seems to be no other properties associated with atomic numbers which are definitely related to the susceptibilities of the elements. May not this fact also emphasize the importance of placing some of the magnetic properties of the elements in the nuclei?

To come back to the field of magnetostriction it would appear from its teaching that in addition to electronic orbits, to explain magnetic susceptibility, *there must be given to the positive nucleus of the atom a property of induction just as Ewing had in his elementary magnets, and, for ferromagnetic substances at least, these nuclei ought to have different dimensions in different directions, capable of being rotated by means of an external field.*

Helmholtz once said,

The disgrace of the nineteenth century is our ignorance concerning magnetism.

What shall we say of the twentieth century?

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FUNDAMENTAL PRINCIPLES ESTABLISHED BY RECENT SOIL INVESTIGATIONS

INTRODUCTION

The following is a brief review of the fundamental principles established by modern methods of soil investigation in the Bureau of Soils in the past twenty or thirty years:

TEXTURE OF SOIL.

The first step taken established the fact of the general influence of the texture of the

[32] Harkins and Hall, *Journ. Amer. Chem. Soc.*, 38, 210, 1916.

[33] Dushman, *l. c.*

soil and its water-holding capacity on the distribution of the great classes of crops; that is, the general relation between the sand, fine sand, silt and clay soils and the general distribution of areas devoted to the production of truck crops, corn, wheat, hay and other heavy farm crops. This together with field studies of origin, mode of formation, and observable physical differences led to the mapping of soils, or the soil survey, which has been extended over a considerable part of the United States.

With the wide field experience it became evident that differences existed between different soil types or in the same soil type that were not to be explained by differences in texture or in water-holding capacity, but that yields vary with the practise of the farmer or from other causes, as was fully known and commented upon by the early Roman writers, that would need to be explained before the practise of agriculture, the application of fertilizers, and the handling of soils could be put upon a truly scientific basis.

ORGANIC CHEMISTRY OF SOILS

The study of some notably infertile soils and of very productive soils of the same type which had been held under what we call "better systems of farming" revealed the presence of certain toxic organic compounds in the one which were not present in the other. This led to a study of the organic chemistry of the soils. Finally we succeeded in separating from soils some 35 definite organic compounds, some of which were beneficial to certain crops and some of which were toxic to certain crops and nontoxic to others. It was also found that soils under a certain condition of aeration would yield certain organic products and under other conditions of aeration other organic products. It was found that the compounds separated from the soil were of the same nature as the compounds in the digestive system and in the blood of man and animal and it was finally realized that the soil has a digestive system as it were and breaks down organic materials such as the proteins, carbohydrates, and fats much

as they are broken down in the digestive system of animals. The soil has the same kind of bacterial, enzymatic and oxidation processes as are common to the animals. It is evident that soil through these digestive agencies will take care of the excreta of plants and the organic matter that accumulates in the soil from various causes, reducing the organic matter to lower and lower forms of oxygenated bodies until they approach the hydrocarbon type of compounds in our humus, which are stable, innocuous and form the sewage disposal of the soil.

In the animal under abnormal functional conditions the too great accumulation of products of metabolism causes a fatigue of the muscles or if the system can not eliminate them the death of the animal. So under abnormal conditions in the soil brought about by adverse methods of cropping, of tillage, of the selection of crops, or improper methods of crop rotation the soil, as the French put it, becomes fatigued and the plant is unable to function.

The second stage of soil investigations therefore has developed the fact that the soil has a digestive system and is liable to fatigue or exhaustion as regards its power to produce crops and is dependent for its efficiency upon normal conditions, much as the animal is dependent upon normal functional activities to maintain life energy. This is a great field opened up for the organic and physiological chemist and bacteriologist. It may be stated more concisely that the chemistry of the soil is running parallel to the chemistry of the animal.

Some of the organic compounds isolated from soils and identified are as follows:

Acrylic acid,	Hentriacontane,
Adenine,	Histidine,
Agroceric acid,	Hypoxanthine,
Agrosterol,	Lignoceric acid,
Arginine,	Lysine,
Creatinine,	Mannite,
Cytosine,	Monohydroxystearic acid,
Dihydroxystearic acid,	Nucleic acid,
Glycerides, liquid,	Oxalic acid,
Guanine,	Paraffinic acid,
Pentosan,	Saccharic acid,
Pentose,	Salicylic aldehyde,
Phytosterol,	Succinic acid,
Picoline carboxylic acid,	Sulphur,
Resin,	Trimethylamine,
Resin acids,	Trithiobenzaldehyde,
Resin esters,	Xanthine.
Rhamnose,	

MINERAL CHEMISTRY OF THE SOIL SOLUTION

The mineral particles that make up the structure of the soil are bathed with a solution containing both inorganic salts and organic compounds. The circulation of this solution is similar in purpose to the circulation of the blood and it is upon this nutrient solution that the plant depends for its nourishment. It is particularly desirable, therefore, that the constitution of this nutrient solution be understood. By handling large quantities of soil in our laboratories it has been possible to obtain large quantities of this soil solution in dilute form. This solution, if allowed to evaporate quietly at ordinary temperatures yields successive crops of crystals which are found to be analogous to the salts found in the Stassfurt deposits of Germany and to the inland lake and sea deposits throughout the world. Silvite, kainite, and carnalite, the three important potash salts of Stassfurt, are commonly present in the nutritive solution of our soils, and, when we come to think of it, it appears to be the simplest thing in the world to understand that the salts that we value so highly in our mines are formed in our soils, transported through the oceans, and crystallized out again when the waters evaporate.

Our chemists have been expressing the results of their analyses in simple conventional terms of single salts. This work shows that the soil solution is most complex and that there are besides single salts, double salts and triple salts. In a complex salt solution changes of temperature or additions of material have a profound effect upon the character of the double or triple salts especially. No correlation has yet been made between these different complexes and the production of crops, or between these different complexes

and the effect of soluble fertilizer materials, or between these different complexes in different soil types, but the way has been opened for chemists now to study the soluble mineral compounds in the nutritive solution of the soil as never before.

The following list of salts has been identified in soils, or obtained from soils through the quiet evaporation of the dilute extracts until crystals appear.

Aphthitalite,	Leonite,
Aragonite,	Loweite,
Blodite,	Magnesite,
Borax,	Mirabilite,
Calcite,	Natrolite,
Carnallite,	Northupite,
Dolomite,	Picromerite,
Epsomite,	Soda niter,
Gaylussite,	Sodium carbonate,
Gypsum,	Sulphohalite,
Halite,	Sylvite,
Hanksite,	Thenardite,
Kainite,	Thermonatrite,
Kieserite,	Tri-sodium phosphate,
Langbeinite,	Trona,
	Vanthoffite.

COLLOIDAL CHEMISTRY—THE ULTRA CLAY

This brings us down to the fourth great fundamental line of research which completes the outline of the problems to consider in future soil investigations and the most difficult of all to understand.

Always in our study of the texture of the soil, we have realized that there was something which modified the texture, something that bound the grains of soil together making certain soils very plastic when wet and very hard compact when dry and making other soils more friable and even incoherent when dry. It took us a long while to determine the cause of this plasticity. It was something that went obviously into solution but did not have the properties of a true solution. Finally we were able to separate it and found that it was a colloidal solution. From this we have prepared and collected the colloid itself, to which we have given the name ultra clay. The examination of this material leads us into the realm of colloidal chemistry which is a most difficult field to investigate because of the extremely inert nature of all materials in a colloidal state.

This ultra clay when dry will absorb as much as 200 times its volume of ammonia gas, from 20 to 40 per cent. of its weight of water vapor in a closed space over free water at 30° C. and in a wet state will absorb from 10 to 30 per cent. of its weight of certain dyes. By heating the ultra clay or an ordinary soil to 900 to 1000° C. this absorptive power is practically completely killed. By measuring the absorption of water vapor, of ammonia, and of certain dyes in the original soil, in the killed soil, and in the ultra clay separated from the soil, we have been able to estimate the amount of ultra clay in soils.

This ultra clay is as strong in its power to cement sand grains as is Portland cement, but when a dry briquette cemented by ultra clay is put into water it goes to pieces while a similar briquette of Portland cement holds its shape and crushing strength. When soil is heated to 900 or 1000° C. it loses almost completely its binding power when formed into a briquette, but if the amount of colloid estimated to be present by the methods already referred to is added to the killed soil the original plasticity is restored and the crushing strength of the dry briquette is about the same as in the original soil.

This colloidal material is disseminated through the soil as a film over the mineral grains, giving plasticity to the soil when wet, and hardness to the soil when dry, and is the medium for the absorption of gases, of organic, and of mineral matters. Physically it is analogous to the muscles and tendons of the animal body, which permits the articulation and motion of the skeleton and its fleshy covering in the animal; chemically it is analogous to the lining of the stomach and other digestive and respiratory organs of the animal and of the protoplasmic content of the vegetable cell. It appears to be essentially a silicate of aluminum and iron. We have not as yet been able to determine whether the small amount of lime, magnesia, potash, and soda present are a part of its constitution

or whether they are held there in colloidal form. The material is so inert in its chemical affinities that we have not yet been able to kill it or to control it in any material way except by heating. This is a matter of the greatest importance in the cultivation of the soil and is a matter of profound importance in road building as it appears to be the main cause of the deterioration and the breaking down of the modern road surfaces.

MILTON WHITNEY

BUREAU OF SOILS,
    U. S. DEPARTMENT OF AGRICULTURE

SCIENTIFIC EVENTS

THE COUNCIL MEETING OF THE AMERICAN CHEMICAL SOCIETY

FROM the report in the *Journal of Industrial and Engineering Chemistry* we learn that Rumford Hall, Chemists' Club, was the gathering place on September 6, of the largest Council Meeting in the history of the society. President Edgar F. Smith was in the chair, and one hundred and sixteen councilors were present in person or by proxy. The business of the day consisted in large part of matters concerning the internal policies of the society, a complete report of which will appear in the proceedings in the October issue of the *Journal of the American Chemical Society*.

Two matters of national policy were discussed at length. The society's committee on patents and related legislation submitted a report on the Stanley Bill, now before the congress. The following resolution was unanimously passed:

While the council is disposed to accept the views of its committee on patents, nevertheless it is felt that a constructive suggestion should be made by the committee as to legislation which would prevent the utilization of our Patent Office by foreigners for the suppression of the development of industries such as was so clearly apparent in the organic chemical industry upon our entrance into the war in 1917. The committee is therefore urged to consider this problem immediately and to report to the committee on national policies.

President Smith outlined the present legislative situation with regard to the organic chemical industry, whereupon it was moved that resolutions urging the passage of a limited embargo on synthetic organic chemicals be prepared for presentation to the general meeting on the following day.

It was decided to hold the annual meeting in September, 1922, at Pittsburgh, Pa. It will be remembered that this section relinquished its lien upon the September, 1921, date to permit the international gathering to be held in New York City. The spring meeting will be held in Birmingham, Ala., early in April, 1922.

The secretary presented an ad interim report of the finance committee and gave statistics regarding the paid and unpaid membership. It is estimated by the directors that the actual expenditures for the year 1921 will exceed the receipts by approximately $10,000.

The president of the Chemists' Club, John E. Teeple, presented a suggestion that the society take over the Bureau of Employment now run by the club, or establish a bureau to replace this organization. In accordance with the Council vote, the President appointed a committee consisting of H. P. Talbot, Edward Bartow, and A. C. Fieldner, to consider this question and report at the spring meeting.

Dr. Smith told of the work of the Priestley Memorial Committee, describing the Priestley portrait, and outlining the plans of the committee to establish a Priestley Medal fund. Plans are also under way for the restoration of the Priestley home at Northumberland, Pa., and President Smith spoke of his wish that the society might celebrate its fiftieth anniversary with a meeting at Northumberland in 1925.

THE OPTICAL SOCIETY OF AMERICA

THE fourth annual meeting of the Optical Society of America will be held in Rochester, New York, on October 24, 25, and 26. A large number of important papers dealing with all branches of optics will be presented. Several of the papers on the program will deal with the various phases of physiological optics. At this meeting a section on vision

will be formed to bring together in one society the workers in different fields on the various phases of physiological optics. In this way, better cooperation will be obtained between the physicist, physiologist, psychologist, and the artist. This year is the centenary of the birth of von Helmholtz and one session of the meeting will be devoted to commemorating his work in the fields of optics, sound, and electricity. An address on "Personal Recollections of von Helmholtz" will be given by Dr. M. I. Pupin. Visits have been arranged to the plants of the Bausch & Lomb Optical Company and the Eastman Kodak Company.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE— SOUTHWESTERN DIVISION

THERE are being given this autumn under the auspices of the Southwestern Division of the American Association for the Advancement of Science a series of lectures on the history of the Southwest. They are being undertaken at the special request of the Frontier Scoutmasters' Association, with the approval and support of the El Paso Council of the Boy Scouts of America. The lectures are as follows:

October 5—The Ancient History of the Southwest as represented by the geological formations of the region: Professor W. H. Seamon, Professor of Geology at the Texas School of Mines.

October 12—The Ancient History of the Southwest as represented by ruins, stone implements, pottery and other remains: E. A. J. Seddon.

October 19—The Spanish Exploration of the Southwest: Mrs. M. D. Sullivan.

October 26—American Occupation of the Southwest: Dr. F. H. H. Roberts, principal of the El Paso High School and president of the Junior College.

November 2—History of the Mining Industry of the Southwest, from the earliest days: Lew Davis, of the El Paso Times.

November 9—History of Irrigation in the Southwest, from the earliest days on: T. H. Claussen, of the U. S. Reclamation Service.

November 16—History of Transportation in the Southwest: G. A. Martin, of the El Paso Herald.

November 23—The Indian Wars in the Southwest: Alvin E. Null.

November 30—The Present and Future of the Southwest: H. D. Slater, of the El Paso Herald.

The second annual meeting of the Southwest Division will be held in Tucson in the latter part of next January. It is expected that the meeting will be largely attended. There will be four scientific sections, instead of three, as at the last meeting. The Stewart Astronomical Observatory will be completed by that time, and Dr. Douglass hopes to dedicate it then as a special feature of the meeting.

ELLIOTT C. PRENTISS,
Chairman Executive Committee

THE TORONTO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE engineering section of the American Association is arranging an important program for the Toronto meeting which will occur from December 27 to 31, 1921. The arrangements for the engineering sessions are in charge of Mr. J. B. Tyrrell, mining engineer, of Toronto. The programs aim to present the application of science to the solution of engineering problems. Many of the addresses will deal especially with the recent accomplishments of scientific engineering in Canada. It will be shown how scientifically trained men have developed some of the natural resources of the Dominion and the means by which this has been accomplished. Addresses already arranged are on the work accomplished by the Hydro-Electric Power Commission of Ontario; on the mines and mining plants of Canada including an account of prospecting in the northern wildernesses; on the explorations for oil carried out in the valley of the McKenzie River by the Imperial Oil Company, and on the work of the Toronto Harbor Commission in improving the Toronto harbor for the accommodation of ships of ocean draft. All of them, and especially those dealing with exploration in the far north, will be of interest not only to engineers but also to geographers and to every one interested in the out-of-doors. These ad-

dresses will generally be accompanied by illustrations and in many cases by motion pictures. Other topics will be announced later.

An exhibit of scientific apparatus will be a prominent feature of the forthcoming Toronto meeting of the American Association. Preparations for the exhibit are in charge of a special committee, resident in Toronto, consisting of Professor E. F. Burton, *chairman,* Mr. L. E. Westman, *secretary,* Professor F. B. Kenrick and Professor R. B. Thomson. The University of Toronto will provide space for the exhibits, and exhibits of non-commercial institutions and private individuals will be exempt from a small charge made to commercial organizations to cover expenses. Those who contemplate taking part in this feature of the Toronto meeting should communicate with the secretary of the special committee.

Reduced railroad fares for those attending the annual meeting of the American Association for the Advancement of Science at Toronto have been granted by four of the large passenger associations, which offer a rate of a fare and one-half, on the certificate plan, for the round trip. The railroad associations that have granted the reduced rates are: The Canadian Passenger Association, which includes practically all of the Canadian railroads; The New England Passenger Association, which includes the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut; The Trunk Line Association, which includes the states of New York, Pennsylvania, Maryland, New Jersey, Delaware, Virginia (in part), West Virginia (in part) and the District of Columbia; and The Central Passenger Association, which includes the states of Ohio, Indiana, Michigan and Illinois. Effort is now being made to secure reduced rates from the other passenger associations. A complete list of railroads offering reduced rates will be given, together with instructions regarding the purchase of tickets on the certificate plan, in the preliminary announcement of the Toornto meeting.

SCIENTIFIC NOTES AND NEWS

Dr. E. D. Ball has resigned as assistant secretary of agriculture. He will remain at the department as director of scientific work.

Professor Mortimer Elwyn Cooley, dean of the college of engineering and architecture of the University of Michigan, has been elected president of the American Engineering Council of the Federated American Engineering Societies.

Sir William Pope has been elected an honorary fellow of the Canadian Institute of Chemistry.

Dr. Dwight C. Bardwell has left Berkeley, Cal., where he received his Ph.D. at the University of California, to accept a position as assistant physical chemist at the Rare and Precious Metals Station of the U. S. Bureau of Mines at Reno, Nevada. Dr. Bardwell will work under Dr. S. C. Lind on research problems presented by the radium at this station.

James E. Ives has resigned his position as research associate and lecturer in physics at Clark University to become a physicist in the office of industrial hygiene and sanitation of the United States Public Health Service. His headquarters will be in Washington, D. C.

Glenn E. Matthews has accepted a position as research chemist in the photographic department of the Eastman Kodak Co., Rochester, N. Y.

Director H. Foster Bain of the Bureau of Mines has appointed a board of engineers, consisting of Mr. M. H. Roberts, Dr. R. C. Tolman and Professor W. L. DeBaufre, to study the production of helium in Texas.

Dr. Louis A. Bauer, director of the department of terrestrial magnetism of the Carnegie Institution of Washington, sailed from New York on October 5 to join the magnetic survey vessel, the *Carnegie,* at Balboa, Canal Zone. He will remain with her until the completion of the present cruise at Washington about the middle of November. Some special investigations are to be undertaken in the Caribbean Sea and Atlantic Ocean during the homeward trip.

DIRECTOR A. A. JOHNSON, of the New York State Institute of Applied Agriculture, who was in Armenia to study conditions for the establishment of industrial and agricultural schools, and later went to Moscow by the request of Secretary Hoover to take charge of the food administration of the surrounding famine area, has completed his mission and has sailed for New York to resume his work.

DR. STEPHEN S. VISHER, a Bishop Museum fellow of Yale University, is studying hurricanes and their effects on man and on the distribution of life in the Pacific. He is now in the Fiji Islands.

WE learn from *Nature* that an expedition to Sumatra, under the leadership of Mr. C. Lockhart Cottle, is to sail towards the end of the year for the purpose of making zoological and museum collections. A special effort will be made to obtain particulars of the life-history of the orang.

ACCORDING to the *Journal* of the American Medical Association, Dr. August Hermeier Wittenborg, professor of anatomy in the medical department of the University of Tennessee, has been refused citizenship in the United States. Failure to register for service in the war was given as the reason for the withdrawal of Dr. Wittenborg's petition for naturalization. Dr. Wittenborg is a German by birth, but has resided in this country for several years.

DR. C. R. STOCKARD, professor of anatomy, Cornell University Medical College, will deliver the First Harvey Society Lecture at the New York Academy of Medicine on Saturday evening, October 22, 1921, at eight-thirty. His subject will be "The Significance of Modifications in Body Structure."

THE first meeting of the Physics Club of the Bureau of Standards for the season will be held on October 17. The speaker will be Dr. A. L. Day, whose subject will be "The Study of California Earth Movements." This is to be the first of a series of about ten lectures on the general subject of physical measurements pertaining to the earth. Meetings of the Physics Club are held on consecutive Monday afternoons at 4:30 in the assembly room of the east building of the Bureau of Standards and are open to all who may care to attend.

MR. J. H. JEANS, secretary to the Royal Society, has been appointed Halley lecturer for 1922, at Oxford University.

THE following lectures have been arranged for delivery at the Royal College of Physicians: The Mitchell lecture, on "The Relations of Tuberculosis to General Conditions of the Body and Diseases other than Tuberculosis," by Dr. F. Parkes Weber, on November 1; The Bradshaw lecture, on "Subtropical Esculents," by Dr. M. Grabham, on November 3; and the Fitz-Patrick lecture, on "Hippocrates in Relation to the Philosophy of his Time," by Dr. R. O. Moon, on November 8 and 10.

DR. ARNO BEHR, a well-known industrial chemist, Perkin Medalist and charter member of the American Chemical Society, has died at his home in South Pasadena, Cal., in his seventy-fifth year.

As has been noted in SCIENCE the board of curators of the University of Missouri has voted to establish a four year course in medicine as soon as hospital facilities can be provided for clinical instruction. For a number of years the medical course at the state university has consisted of two years. We learn from the *Journal* of the American Medical Association that the extra session of the legislature, recently adjourned, appropriated $250,000 for the erection of a state hospital at Columbia for the purpose of providing clinical material for the medical students. It is expected that a similar sum will be appropriated at each session of the legislature until $1,000,000 has been appropriated for hospital facilities. The legislature also appropriated $200,000 for the erection of a new building for State Hospital No. 2 at St. Joseph.

ON September 22, President Harding by public proclamation accepted and added to the present Muir Woods National Monument, California, 128.14 acres of land, a gift to the

United States from Mr. and Mrs. William Kent, of California, and from the Muir Woods and Mt. Tamalpais Railroad. The Muir Woods, a notable grove of redwood trees, became the property of the United States on June 9, 1908, when Theodore Roosevelt accepted 295 acres from Mr. and Mrs. Kent and proclaimed the area a national monument. Situated on the south slope of Mt. Tamalpais about seven miles in a direct line across the bay from San Francisco, it contains numerous redwood trees, reaching to a height of 300 feet and having a diameter at their base of 18 or more feet.

Nature states that a joint research committee has been formed by the National Benzole Association and the University of Leeds which will take over the direction of research in the extraction and utilization of benzole and similar products in England. The National Benzole Association is concerned with the production of crude and refined benzole, and, according to its constitution, one of its objects is to carry on, assist, and promote investigation and research. The term "benzole" is used in its widest sense, so the field of activity of the association embraces carbonization and gasification processes, by-product coke-oven plants, gasworks, etc., but at the present time it is concerned mostly with the promotion of home production of light oil and motor spirit. Success in this direction is thought to rest largely with chemical investigations into the possibilities of the various processes concerned, and it is with this object that cooperation with the university is sought. The joint committee which has been formed consists of equal numbers of representatives from the university and the association, and the initial membership is as follows: Professor J. W. Cobb, Professor J. B. Cohen, Professor A. G. Perkin, Professor Granville Poole, Professor A. Smithells, Mr. W. G. Adams, Dr. T. Howard Butler, Mr. S. Henshaw, Mr. S. A. Sadler, and Dr. E. W. Smith. Research work undertaken will be carried out under the supervision of Professor Cobb, and reports embodying the results will be published at intervals.

THE *British Medical Journal* writes: "At the request of the Surgeon-General of Trinidad, made through the American consul in that island, the surgeon-general of the United States Public Health Service has, with the consent of the Treasury Department, undertaken to send to Trinidad a quantity of the chaulmoogra oil preparation used by that service for the treatment of leprosy. The amount to be supplied will be sufficient for 500 treatments. The courtesy of the United States government departments concerned must be freely acknowledged; but the fact that the government of the United States was applied to by the medical authorities of an important British colony for this assistance appears to show that there is something lacking in the relations between the colonial medical authorities abroad and at home, and in the cooperation between the different British government departments, more particularly as the researches on the therapeutics of chaulmoogra oil in leprosy have been largely carried out by distinguished officers of the Indian Medical Service."

UNIVERSITY AND EDUCATIONAL NEWS

THE General Education Board has given Vassar $500,000 to increase the salaries of the faculty. Toward this sum $100,000 has been promised by Mrs. Edward S. Harkness on condition that $1,500,000 more be raised within two years.

THE new medical building of the University of Alberta has now been completed. The support of the people of the province has made possible the establishment of a well-manned and well-equipped medical school, which together with several closely allied hospitals can undertake the thorough education of medical and dental practitioners.

DR. JOHN LEE COULTER has been elected president of the North Dakota Agricultural College. He takes the place occupied by Dr. E. F. Ladd, who was elected to the United States Senate last March.

DR. P. W. WHITING, of St. Stephens College, Annandale-on-Hudson, N. Y., has resigned to take up work as associate research

professor of eugenics in the child-welfare research station of the State University of Iowa.

Dr. Ralph F. Shaner, for several years connected with the department of anatomy of the Harvard Medical School, has entered on his work as assistant professor of anatomy in the University of Alberta.

Dr. D. Burns, Grieve lecturer on physiological chemistry in the University of Glasgow, has been appointed professor of physiology in the University of Durham College of Medicine, Newcastle-upon-Tyne, in succession to the late Professor J. A. Menzies.

DISCUSSION AND CORRESPONDENCE
THE CAUSES OF WHITENESS IN HAIR AND FEATHERS

My attention has recently been called to a statement by W.D. Bancroft[1] to the effect that white hair and feathers owe their color to the entrance of air into their structure. Similar statements have appeared elsewhere at various times, and this conception appears to be widespread.

No one, to my knowledge, has ever presented any real evidence that either hair or feathers have any more air in them when white, than when colored. Furthermore it is quite unnecessary for them to have more air. I have never been able to see any difference in the structure of white hair and feathers as compared with colored hair and feathers, except for the presence or absence of pigment.

In 1904, I made the statement, in an address, that hair and feathers are white for the same reason that powdered ice or glass and other transparent substances in a fine state of division appear white.[2]

Hair consists of numerous cornified epithelial cells more or less *incompletely* fused together. In the case of human hair, most of the structure is cortical. These cells furnish a vast number of external and in-

ternal reflecting surfaces, as can be seen easily by placing a white hair on the microscope stage with no mounting fluid. When pigment is present, the incident light is more or less extensively absorbed, according to the amount of pigment, before reaching the deeper cells. The amount of undispersed light reflected, of course depends on the number of internal reflecting surfaces not screened by pigment. There is always some reflection of undispersed light by the hair cuticle, no matter how much pigment is present.

The white of feathers is produced mostly by the barbules which are of microscopic size and consist of single columns of cells.

Hair and feathers have many times the surface, external and internal, provided by small bodies of similar mass but less intricate structure. According to a well-known law, the surface of a cube varies relatively to the volume inversely as the diameter. Thus a cuboidal cell one tenth of a millimeter in diameter has ten times as much surface, relatively, as a body one millimeter in diameter. Furthermore, the amount of reflecting surface is increased by the irregular contour of the hair and feather elements. The total area of the vast number of facets in a single, unpigmented hair or feather which are in a position to reflect light to the eye is relatively very great.

White in hair and feather structures is due to failure or absence of pigment formation in the follicle before cornification takes place. I know of no critical evidence that either hair or feather structure can become white in any other way. The process is therefore slow, and the time required for a change to white is determined by the rate of growth.

Similar views are expressed in an article by Stieda[3] where a discussion of the origin of the notion that hair may suddenly become white is discussed in detail.

R. M. Strong

Loyola University School of Medicine,
    Chicago, Ill.

[1] Applied Colloid Chemistry, 1921, p. 198.

[2] See abstract in *Biol. Bull.*, 1904, Vol. VI., No. 6, p. 311, for remarks about white feathers. See also *Anat. Rec.*, 1918, No. 1, p. 52, for discussion of white hair.

[3] *Verh. der Gesellsch. Deutscher Naturforsch. und Aerzte.*, 1910, Bd. 81, S. 222–224; also *Anat. Hefte*, 1910, Bd. 40, H. 2.

SIDEWALK MIRAGES

To the Editor of Science: A number of communications, published in Science during the past year, on "Sidewalk mirages" having recently come to my attention, I would like to add my experience with this phenomenon to those which have been related. I have driven over a stretch of road, part asphalt and part concrete, daily for the past two years, and have looked for mirages under every condition of the weather. Over the distance of the three miles of roadway I have marked every spot where the mirage occurs.

The nature of the road surface seems immaterial, but the effect of a "water surface" can be obtained wherever the level of the eye approaches that of the road surface. The mirage is not visible in cold winter weather and it is best during the very hot days in July and August. I believe that the intensity of the effect is unquestionably a function of the temperature of the road surface and the air immediately above it. That one observes a true mirage in this phenomenon and not a simple reflection can be demonstrated by the fact that an object "mirrored" on one of these surfaces will show an angle of incidence of probably 45° or greater, whereas the angle of reflection is, as stated previously by another observer, very small, approximating a few degrees only.

Mirror-like effects on asphalt roads are common, but have not the clarity of the images seen in a mirage, nor can mirror effects, due to reflection simply, be seen on a concrete road, so far as I have observed.

The position of the sun is of no influence, as mirages have been observed at the same spot at all times of the day.

ALLAN F. ODELL

CARNEY'S POINT, N. J.

DISCOVERY OF A PREHISTORIC ENGRAVING REPRESENTING A MASTODON

To the Editor of Science: It may be of interest to you to learn of the recent reexamination of Jacobs' Cavern, a prehistoric rock-shelter located in extreme southwest Missouri, some three miles from Pineville, county seat of McDonald County. This cavern was examined by Dr. Charles Peabody and Mr. Warren K. Moorehead, of Phillips Academy, in 1903, report of their examination appearing in 1904 in Bulletin No. 1, "Exploration of Jacobs' Cavern."

Subsequent periodical and amateur investigations carried on by the writer, who now owns the land upon which this cavern is located, have resulted in the discovery of a number of very interesting artifacts. Chief among these are bone and horn awls, flint implements, engraved and polished implements of stone, and shaft straighteners and smoothers. Portions of an adult human skeleton, accompanied by an engraved sandstone pipe, have also been found.

The latest discovery was made on April 17, 1921, when the writer and Mr. Vance Randolph exhumed several engraved, perforated, and otherwise ornamented bones. These were apparently firm and sound but as a precautionary measure pen drawings were made immediately. Nevertheless, upon being examined a few weeks later, it was found that the bones were rapidly disintegrating. Immediate preservative treatment was resorted to but was so limited by local conditions that it was found impossible to save more than the most important specimen.

In many respects this bone is very interesting. One side bears an engraving which prominent archæologists have agreed seems to resemble a mammoth or mastodon. The reverse side bears two rows of parallel zigzag lines, lengthwise of the bone, the design corresponding closely with those found on the sandstone pipe. This design is also accompanied by another evidently intended to represent some member of the deer family.

The writer felt that Phillips Academy was naturally entitled to priority rights of reexamination of the cavern. However, Mr. Moorehead found it impossible to visit the cavern and recommended that Dr. Clark Wissler, of the American Museum of Natural History, make the examination. Dr. Wissler is now on the ground for that purpose.

Photographs of the most important specimens are in process of preparation and a

detailed report of operations will be made public as soon as practicable.

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SOME SUGGESTIONS FOR PHOTOGRAPHING FOSSILS

FOR some time the writer, when photographing fossils, has used the whitening process contributed by Professor S. H. Williams, but, with many others, he has found it not altogether satisfactory. In order that the whitened specimen should contrast with a white background it has been necessary to over-expose or over-develop the prints. Because of this, many of the minor details of fossils have been lost in reproduction, and the pictures, as a rule, have seemed flat and "lifeless." In addition, it is usually the practise to opaque the background of the negative as an aid in determining how far to carry the development of the print. This process is painstaking and slow at best.

Some time ago, the writer, with the assistance of Mr. Parke Bryan, developed a slight variation in the photographing of whitened fossils that seems to be a decided improvement. The time required is materially shortened, in that the negative requires no opaquing, and the results are so gratifying in the way of improved reproductions that it seems worth while to outline briefly the method.

The method is a combination of the common lighting arrangement used in portrait photography, and the whitening process of Professor Williams. The specimen is mounted on a slender stick with modeling clay and then coated with a thin film of white. A dull white background, placed some distance behind the specimen, is turned at an angle such that it receives the full light but does not reflect it toward the camera. After the photographing table is orientated so as to give the conventional light direction and the desired lightshade contrast to the relief features, a screen is placed between the specimen and the source of light so as to intercept the direct rays. The screen consists of one or more thicknesses of cheesecloth sewed on a wire frame, the number of thicknesses depending on the intensity of the light. Every feature of the fossil now shows clearly on the ground glass of the camera, although the specimen appears dark against a pure white back.

It has been found that the shadows on the under side and away from the light source are more intense than the image on the ground glass indicates, and except in the case of relatively flat specimens it has been necessary to use a slight back reflection. A sheet of dull finish white cardboard held at the proper angle has in every case been sufficient for this purpose. If an actinometer is used to determine the time of exposure, it is obviously the light of the shaded specimen that is to be tested.

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SCIENTIFIC BOOKS

Vitamines: Essential Food Factors. By BENJAMIN HARROW, Ph.D. New York, E. P. Dutton & Co., 1921. Pp. 219. Price $2.50.

The author of this book has been at great pains to popularize a subject which the laity will certainly be glad to have so clearly presented. About half the volume is preliminary to the specific topic; it is a general account of nutrition and the story is well told. One is disposed to wonder whether readers who require such a very elementary introduction will appreciate the later chapters which are of necessity more difficult. However, a rare degree of order and simplicity is maintained to the end. The writer has a judicial attitude; he does not assert opinions of his own but quotes others with fairness and has evidently been in correspondence with the leading investigators that he may accurately express their views.

Of course not much space can be devoted to controverted matters in a book of this character. But a dogmatic tone is avoided. It should be plain to the reader that many problems await solution. Among the questions not fully settled may be mentioned the

following: whether rickets is due to lack of Fat Soluble A, whether there is an antiscorbutic vitamine (Water Soluble C), and in what sense pellagra may be rated as a deficiency disease. All the material is handled in a cautious and modest way with the result that no encouragement is given to faddists of any kind.

PERCY G. STILES

EXPERIMENTS ON THE RECORDING AND REPRODUCTION OF CARDIAC AND RESPIRATORY SOUNDS

WE have recently conducted experiments at the Bureau of Standards in which permanent records of cardiac and respiratory sounds have been made and reproduced by the use of a telegraphone. The records have also been made audible throughout the room with the aid of audion amplifiers and a loud-speaking telephone.

A carbon telephone transmitter of ordinary type with a rubber adapter substituted for the mouthpiece was used for the stethoscope. The currents from the telephone transmitter were amplified by means of a five-stage audion amplifier which was connected to the recording element of a steel wire telegraphone. The magnetic records of the cardiac and respiratory sounds thus obtained were made audible by connecting telephone receivers to the telegraphone in the usual manner. The telegraphone currents were also amplified by means of a three-stage audion amplifier which was connected to a loud speaking telephone. In this way the sounds were made audible throughout the room.

This method of obtaining permanent records of cardiac and respiratory sounds and of reproducing them offers interesting possibilities in the study of normal and pathological conditions of the heart and lungs and their demonstration to an audience for purpose of instruction.

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SPECIAL ARTICLES

THE SEPARATION OF THE ELEMENTS CHLORINE AND MERCURY INTO ISOTOPES

IN SCIENCE of March, 1920, Harkins and Broeker reported that they had obtained a separation of chlorine into isotopes by diffusing hydrogen choride gas. The separation at that time amounted to an increase of atomic weight equal to 0.055 unit, or a change of density amounting to 1,550 parts per million. This separation has been definitely confirmed by Dr. Anson Hayes and the writer, who have secured an increase of 0.04 unit of atomic weight in a larger quantity of material. Elaborate purifications have been resorted to, and definite evidence has been secured to show that the increase in density found is actual, and not due to impurities. The details of this work were supposed to have been printed in the August number of the *Journal* of the American Chemical Society. However, since the date of publication of this number is doubtful on account of the printers' strike, it seemed advisable to answer here the considerable number of inquiries as to whether we have secured definite evidence of the separation.

About six months after our notice of the separation of chlorine into isotopes had been published, Bronsted and von Hevesy published a notice in *Nature* indicating that they had separated mercury into isotopes. However, since the extent of the density change reported by them was only about *one thirtieth* of that previously obtained by us in the case of chlorine, it seemed to us that the evidence for this separation of mercury was inconclusive, since a change of 50 parts per million in density might be due to minute amounts of impurities. In order to see if they could confirm these results, Dr. R. S. Mulliken and the writer have vaporized mercury at low pressures. The mercury was carefully purified by five fractional distillations in air at low pressures, and one in a high vacuum, after initial purifications with nitric acid. The increase in density obtained amounts to 69 parts, and the decrease to 64 parts or a total

change of density of 133 parts per million, or 0.027 unit of atomic weight.

The evidence that a separation has actually been obtained rests in the quantitative agreement between our results and those of Bronsted and von Hevesy, with respect to the rate of separation (efficiency of process). If we consider the efficiency of our more ideal apparatus as 100 per cent., that of the other investigators is 75 per cent. while that of our less ideal apparatus used in the greater part of the work in order to save the expense of carbon dioxide as a cooling agent, was 93 per cent. when the vaporization was slow, and as low as 80 per cent. for a rapid vaporization. We have obtained evidence that there is a slight separation of isotopes produced when mercury is *distilled* slowly at a sufficiently low pressure.

The rate of separation of two isotopes varies as the *square* of the difference of their atomic (or molecular) weights, and the product of their mol fractions, as the logarithm of the cut, and inversely as the atomic (or molecular) weight.

A diffusion coefficient has been calculated to represent the relative separation of isotopes attained in terms of the atomic weight change, when a definite cut is made. The values are 0.00843 for neon, 0.00868 for magnesium, 0.00450 for lithium, 0.00758 for nickel, while the experimentally determined coefficient for mercury is 0.00570. For chlorine the coefficient is 0.00950 for hydrogen chloride, 0.00690 for methyl chloride, 0.00494 for chlorine, 0.00413 for methylene chloride, 0.00295 for chloroform, and 0.00229 for carbon tetrachloride.

It is of interest to note that there are 9 isotopic forms of $MgCl_2$ (or more if there is a chlorine of atomic weight equal to 39), 7 of C_6Cl_6, and if mercury consists of 6 isotopes, there are 63 isotopic forms of Hg_2Cl_2. In addition to this most of the isotopic forms of C_6Cl_6 consist of a number of space isomers.

<div align="right">William D. Harkins</div>

University of Chicago,
August 30, 1921

AN ARTIFICIAL NERVE

Physiologists are keenly interested in all attempts to discover an explanation or an analogy for the passage of the nerve stimulus. Most enlightening suggestions have recently been presented by Lillie[1] in his studies of passivity phenomena in pure iron wires. It seems that the transmission of the momentary wave of activity which occurs in a passive iron wire on activation in 70% nitric acid is closely analogous both chemically and electrically to the passage of the nerve impulse.

The general similarity of the two phenomena was apparently first noticed by Wilhelm Ostwald and subsequently elaborated by his student Heathcote.[2] In a paper published in 1907 under the caption "Transmission along a nerve" (p. 909) Heathcote writes as follows:

In 1900, then, Prof. Ostwald called our attention to the possibility of nerve transmission being a process akin to the transmission of activity. . . . It is to be expected . . . that transmission of activity would be slower immediately after the first transmission owing to products of reaction around the iron. This has been confirmed by direct experiments in the case of iron in nitric acid. An effect of this kind in a nerve would explain the nature of "fatigue" so far as it concerns nerves.

After discussing the small amount of energy consumption in both transmissions Heathcote summarizes his conclusions as follows:

There is nothing in the structure of nerve which renders it impossible to regard transmission as occurring in a way which is analogous to the transmission of activity along passive iron. . . . It appears possible too that the network in protoplasm may be a layer capable of transmitting changes in a similar way and which manifest themselves as an essential part of the mechanism of irritability.

It is not surprising that Heathcote's paper should have escaped the attention of physiolo-

[1] Lillie, R. S., '18, Science, 43, 51; '20, *J. General Physiol.*, 3, 107.

[2] Heathcote, H. L., '07, *J. Soc. Chem. Industries*, 26, 899.

gists. Lillie's independent rediscovery of this analogy, however, and his detailed studies and analysis strengthen the probability of a fundamental relation subsisting between the two phenomena.

The passage of the wave of activation over the surface of a short wire is so rapid, that it is not easily demonstrated to a large group of students. The simple arrangement here described is clearly visible at a considerable distance and has been used successfully as a lecture table demonstration.

Nine and a half meters of a ten-meter piece of number 20 piano wire are wound by hand on a machine lathe into a spring small enough to slip easily into a 100 c.c. burette. After stretching the spring sufficiently to insulate the individual turns, a glass tube is inserted in the spring and the remaining half meter of wire is returned through this tube. When
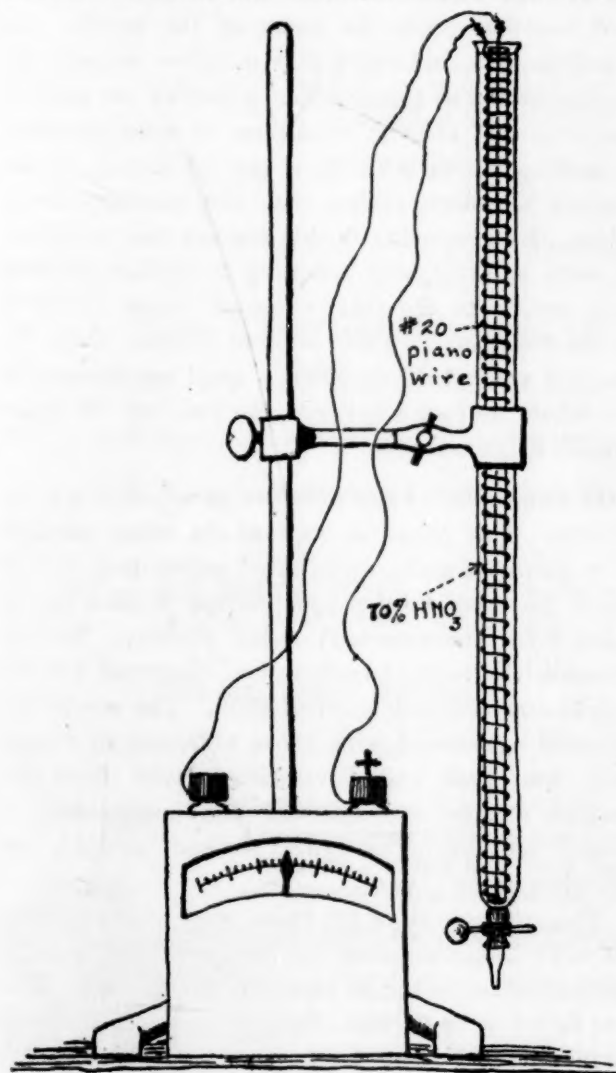

FIG. 1

set into the burette the upper end of this tube should just reach the burette top (Fig. 1). The two free ends of the piano wire are now connected through thin iron wires with a demonstration galvanometer or voltmeter which registers both positive and negative variations. After filling the burette three quarters with 70 per cent. c.p. nitric acid (by volume) the spring coil is lowered into it until about an inch of the lower end of the coil is submerged in the acid. The submerged inch of wire immediately begins to dissolve but if the coil is held in this position until chemical action ceases, the entire wire may be lowered into the acid without further action. In other words by passifying one end of a wire and then slowly lowering the remainder of that wire into acid the entire piece is passified. To prevent activation the wire must be lowered slowly and steadily. The coil is now ready to be tested at intervals with a zinc or copper "stimulus" applied just at the surface of the nitric acid at the top of the burette. After a somewhat variable latent period the entire spring becomes activated. The wave of activation passes down the coil and back through the return wire registering a diphasic "action current" on the galvanometer.

In its passage down the spring the activation wave sets free a shower of minute bubbles which change the color of the acid sufficiently to make the wave of activity clearly visible even at some distance from the preparation. This preparation recovers rapidly at room temperature and may be used repeatedly to demonstrate mechanical, chemical and electrical stimulation as well as the time required for the passage of a single activation wave over a distance of ten meters. At the close of the demonstration the coil should be removed from the burette, thoroughly rinsed in slightly alkine water and alcohol and rubbed briskly with a rough cloth. With these precautions it may be used repeatedly.

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II

Propylene glycol dinitrate: CHARLES E. MUNROE. During the Great War not only was the demand for glycerine for use in making nitroglycerin greatly increased, but, as glycerine is normally produced from fats and oils which grew in demand for use in food, there was a special shortage in the supply. A promising substitute, though not a full equivalent for this, was found in propylene glycol dinitrate. Propylene glycol dinitrate is a nitric ester produced by the nitration of one of the isomeric forms of propylene glycol, which latter is the second member of the group of dihydroxy alcohols or glycols. The nitration of the glycol to produce this explosive is carried on in the same manner and with the use of the same acids as that of glycerine to produce nitroglycerine and the product has a similar appearance to the latter. The results of tests reported show that this propylene glycol dinitrate may be used as nitroglycerine is in the manufacture of dynamites and blasting gelatins. It is found to be less sensitive, to have a lower freezing point, to be decidedly more volatile, and to develop less strength than nitroglycerine, but in an emergency it may be efficiently used as an explosive, especially in mining and other industrial operations.

Further investigations concerning the relations between terrestrial magnetism, terrestrial electricity, and solar activity: LOUIS A. BAUER. The following chief facts have resulted from the present investigation: (1) The earth's average intensity of magnetism, as well as the strength of the electric currents circulating in the earth's crust, decreases with increased solar activity. The change between minimum and maximum sunspot activity in the case of the former may amount to six per cent. and more and in the case of the latter one hundred per cent. and more. (2) The atmospheric potential-gradient, or the deduced negative charge on the surface of the earth, increases with increased solar activity, the range in the variation between minimum and maximum sunspot activity being about 15 to 20 per cent. The electric conductivity of the atmosphere, on the other hand, shows but little, if any, systematic variations during the sunspot cycle. Accordingly, since the vertical conduction-current of atmospheric electricity is derived from the product of the potential-gradient and the electric conductivity, it is found that this vertical current increases in strength with increased solar activity; the range of the variation between the minimum and maximum sunspot activity is about 20 to 25

per cent. It would thus appear that atmospheric electricity, like terrestrial magnetism, is controlled by cosmic factors. These new results have an important bearing upon theories of atmospheric electricity. (3) Regarding the daily and monthly fluctuations in terrestrial magnetism, earth currents, and atmospheric electricity, as measured by the quantity, $H R$, where H is the intensity of the field and R the range in the element during the period considered, it is found that while in general, the magnetic and earth-current fluctuations increase with increased solar activity, the electric fluctuations, as shown by potential-gradient observations, apparently decrease with increased solar activity. (The latter result, however, should be regarded as but a preliminary one and it is receiving further investigation.) (4) Instead of using the sunspot numbers direct for comparison with magnetic and electric variations, it is found that a more satisfactory measure of solar activity may be based upon the monthly range of sunspot frequency, or upon the average numerical departure of the daily sunspot numbers from the mean of the month. In brief, there is indicated that a better measure of the radiations and emanations affecting the earth's magnetic and electric conditions is some quantity measuring the variability, or rate of change, in the sunspot numbers, rather than the numbers themselves. By measuring in this manner the variations in solar activity, and adopting a similar measure with regard to the solar constant values obtained by the Smithsonian Institution at Calama, Chili, for the two years 1919 to 1920, a good agreement, on the whole, is found between the two sets of measures of solar activity.

On mean relative and absolute parallaxes: KEIVIN BURNS. This paper shows that the mean parallax of a group of stars, distributed at random, is 3.56 times the mean total proper motion divided by the mean total (uncorrected) radial velocity. By this formula the mean parallax was computed for the bright stars of each spectral class. The results are in good agreement with those obtained by Campbell, who used radial velocities freed from the motion of the sun and the tau components of proper motion. The newer method is much less laborious.

The mean parallax for those stars whose relative parallax has been observed was computed and the correction to reduce to absolute was derived. This was found to be 0.″010. This correction is the mean parallax of the comparison stars, which is in fair agreement with the value derived from the mean proper motion of these stars.